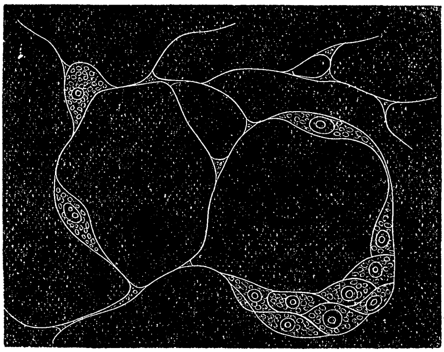
LIFE HISTORIES OF THE PROTOZOA.

BY A. S. PACKARD, JR.

IV. THE LABYRINTHULÆ.

WE would not pass over certain forms doubtfully referred to the Protozoa, by Cienkowski, the only one who has studied them, and placed by Hæckel near the Diatoms and Desmids, in his

Fig. 12.



Labyrinthula.

kingdom "Protista," but which may be provisionally located near the Rhizopods. These organisms were found by Cienkowski at Odessa beneath the seaweeds growing on the piles in the harbor. They are minute, orange-colored organisms, forming reticulated threads which enclose spindle-shaped nucleated bodies. Fig. 12, represents *Labyrinthula macrocystis*, highly magnified, with the single spindle-shaped bodies starting out from the mass on the left, and gliding over the "rope walk," or framework of threads. Cienkowski gives the following results of his investigations on the nature of these singular organisms, which we hope may be discovered in this country:

1. They present masses of cells which enclose a nucleus, and which increase in number by division; they possess a certain degree of contractility, and now and then are covered with a cortical substance.

2. These cells exude a fibrous substance, which makes a stiff, tree-like network, forming a branching framework.

3. The cells leave the mass and glide in different directions along the framework to the periphery of the mass. The Labyrinthula cells can only continue their peregrinations when supported by this line of threads.

Development. The moving cells unite in a new mass and become cysts, in which each cell is surrounded by a hard covering, the whole being held together by a rind-like substance.

After some time four small granules are formed from each cyst, which most likely become young Labyrinthula cells.

He concludes that "these peculiar organisms bear no relation to any known group of beings of either of the organic kingdoms. They cannot be classed with the sponges, Rhizopoda, Gregarinæ, or ciliated Infusoria, or with the algæ or fungi."

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V. THE FLAGELLATA.

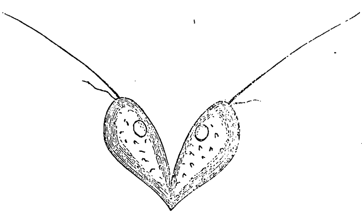
As with the Amœba-stage of the lower Protozoa, so we have had anticipations of the Monads, as the Flagellata may be popularly styled, in the zoospores of the lower Protozoa and Monera. The monads in point of structure are scarcely more highly organized in their lowest forms than the spores of the algæ and the zoospores of the other Protozoa, for which they are often mistaken. They are exceedingly minute, oval bodies, with a nucleus and contractile vesicle and one or two long whip-like cilia, whence the term *Flagellata.*

The true monads have been studied by the late Professor H. J. Clark with more success than by any one else. *Monas termo* Ehr.? is much like single individuals of *Urella glauconia* Ehr.? (Fig. 13), though the body is shorter and more regularly oval. It is faint olive in color. The monads are provided with one or more flagella, or bristle-like cilia, situated in *M. termo* on the front near the beak-like prolongation of the body. In swimming the monad stretches out the flagellum, which "vibrates with an undulating, whirling motion, which is most especially observable at its tip, and produces by this mode of propulsion the peculiar rolling of the body, which at times lends so much grace to its movements as it glides

from place to place" (Clark). When the monad is fixed the flagellum is used to convey food to the mouth, which lies between the base of the flagellum and beak, or "lip," as Clark calls it. The food is thrown by a sudden jerk and with precision, directly against the mouth. "If acceptable for food, the flagellum presses its base down upon the morsel, and at the same time the lip is thrown back so as to disclose the mouth, and then bent over the particle as it sinks into the latter. When the lip has obtained a fair hold upon the food, the flagellum withdraws from its incumbent position and returns to its former rigid, watchful condition. The process of deglutition is then carried on by the help of the lip alone, which expands latterly until it completely overlies the particle. All this is done quite rapidly, in a few seconds, and then the food glides quickly into the depths of the body, and is enveloped in a digestive vacuole, whilst the lip assumes its usual conical shape and proportions."

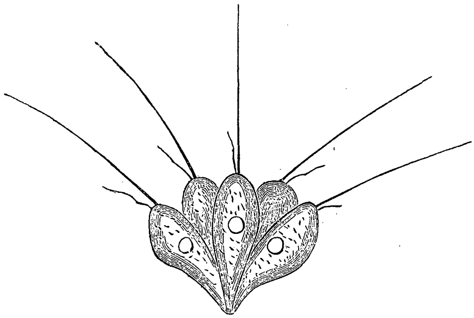
All the monads have a contractile vesicle. In *Monas termo*, Clark observes that it is "so large and conspicuous that its globular form may be readily seen, even through the greatest diameter of the body; and contracts so vigorously and abruptly, at the rate of six times a minute, that there seems to be a quite sensible shock over that side of the body in which it is embedded." The contractile vesicle is thought to represent the heart of the higher animals. The reproductive organ may possibly, says Clark, be represented in *Monas termo*, by a "very conspicuous, bright, highly refracting, colorless oil-like globule which is enclosed in a clear vesicle" called the nucleus. This and other monads live either free, or attached by a slender stalk. As an example of the compound or aggregated monads may be cited *Urella* (Fig. 13), probably *glauconia* of Ehrenberg, of which an account, with accompanying figures, here reproduced, was published by Prof. A. H. Tuttle in the AMERICAN NATURALIST, vi, 286. Figs. 13, 14 and 15 represent two, five, and about forty monads of this species, magnified 1000 diameters. Fig. 16 is an ideal section through a colony of this monad. Urella, as Tuttle observes, "probably

Fig. 13.



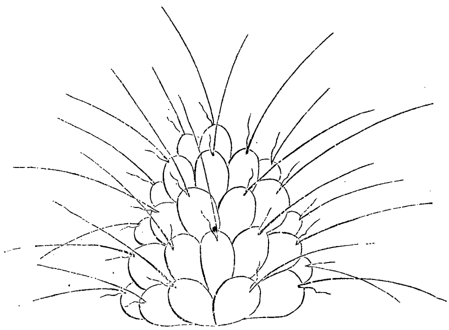
Urella.

Fig. 14.



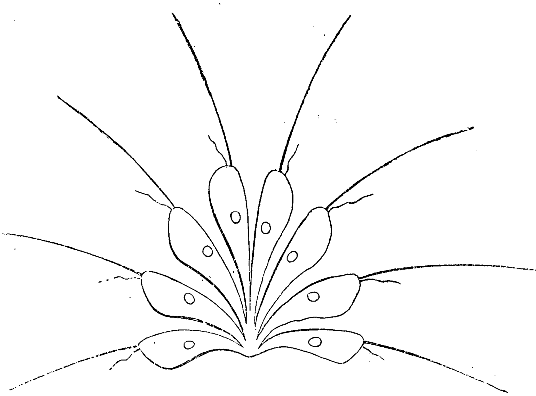
A group of five Monads (Urella).

Fig. 15.



A colony of about forty Monads (Urella).

Fig. 16.



Ideal section through a colony of Urellæ.

finds its nearest ally in Anthophysa, differing from that genus principally in being free swimming instead of fixed upon a stalk." The genera Chlamydomonas and Colpodella are represented at Fig. 20, B. A higher form than Monas is Codosiga (Fig. 17) in which the oval body is stalked and continued in front into a very high membranous bell-shaped collar. Other monads are certain human parasites, *i.e.*, *Cercomonas urinarius*, *C. intestinalis* and *Trichomonas vaginalis*.

The second family of monads are the *Astasiœa*. Here belong Astasia and Euglena (Fig. 18). The former genus is somewhat amœba-like in the changes which it undergoes, its body, according to Clark, during its amœboid retroversions becoming "contorted into a shapeless, writhing mass." They have a conspicuous, red so-called "eye-spot." A similar organ occurs in the zoospores of some algæ.

The third family of Flagellata, the *Peridinea*, is represented by Heteromastix, Dysteria, Pleuronema, Peridinium and Ceratium. Clark observes that Heteromastix is a transitional form connecting the Flagellata with the Ciliata or true Infusoria. Dysteria is still nearer to the Infusoria. Clark describes it as a two-shelled infusorian, with the open space between the shells provided with "a row of closely set, large vibratile cilia," with one larger than the others, the true flagellum. After a careful description of this organism he concludes that "in all the organization of this animal there is nothing which is not strictly infusorian in character. The jaw-like bodies are not confined to this alone, for there are quite a number of others which possess a similar apparatus at or near the mouth. Chilodon has a complete circle of straight rods around the mouth. As for the pivot it is nothing but a kind of stem, such as exists on a larger scale in Stentor, or is more particularly specialized in the pedestals of Epistylis, Zoothamnium, or Podophrya; and as counter to what we see in these last, I would state that there are certain of the Vorticellians closely related to Epistylis, which have no stem whatever, and swim about as freely as Dysteria."

The Monads are divided into three families, thus characterized by Claus in his "Grundzuge der Zoologie:"

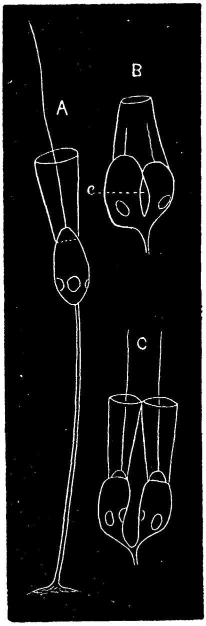
1. *Monadina.* Body small, rounded, naked or with a tough membrane; resembling the zoospores of algæ, etc.

2. *Astasiœa.* Body naked and changeable like the monads, only bearing flagella.

3. *Peridinea.* Body having, besides the flagellum, a row of cilia.

Development. The common form of reproduction is by simple self-division. Clark describes this as he observed it in *Codosiga pulcherrimus* (Fig. 17, A). The act requires forty minutes. The first sign of fission is a bulging out of the collar, which becomes still more bell-shaped. The flagellum next disappears. Then marks of self-division appear in a narrow, slight furrow (Fig. 17, B, *e*), extending from the front half-way back along the middle of the body. Meanwhile the collar, which had become conical, expands, and, most striking change of all, two new flagella appear. Then the collar splits into two (Fig. 17), and soon the two new Codosigæ become perfected, when they split asunder, and become like the original Codosiga. Such is the usual mode of multiplication of the species in the monads.

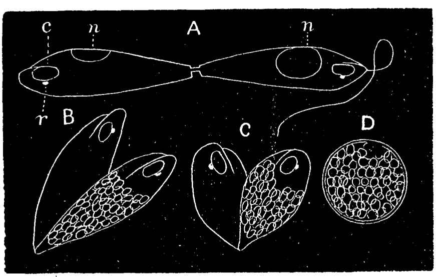
Fig. 17.



Fission of Codosiga.

A second mode, that of becoming encysted, has been rarely observed. Carter, so far as we are aware, was the first to attempt to trace the life history of a monad. We copy the following figures from his memoir. Fig. A represents two *Euglena viridis* in conjunction; *n*, the nucleus, *c*, contractile vesicle, and *r*, the red body; B and C the same after the breaking up of the contents into the embryonic zoospores. The two Euglenæ finally

Fig. 18.

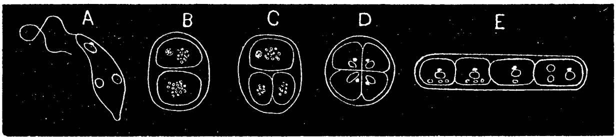


Development of Euglena viridis.

separate and each becomes spherical, encysted as at D. Fig. 18 illustrates the mode of development in *Euglena agilis*. A repre-

sents the adult Euglena, taken from the brackish water of marshes at Bombay; B, the resting stage, transverse division having taken place, and showing that the red body is not developed in the lower

Fig. 19.

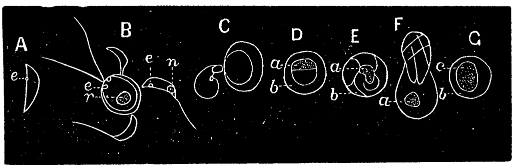


Development of Euglena agilis.

half; D, the same, with a quadruple longitudinal division, showing that the red body is equally multiplied; E, linear development, probably by longitudinal division, as the red body is present in each cell.

We copy a portion of the figures and account of the development of *Colpodella pugnax* as given by Cienkowski. Figure

Fig. 20.

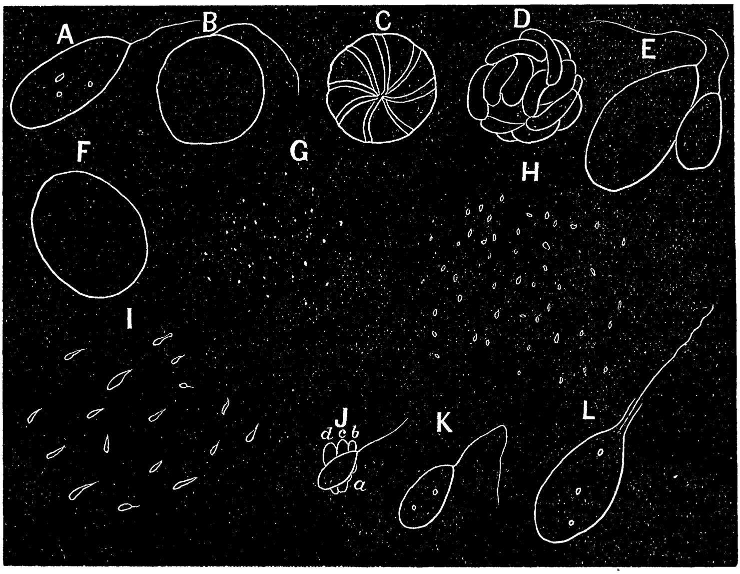


Development of Colpodella.

20, A, represents this monad before taking food; B represents three Colpodellæ in the act of absorbing the nucleus of a Chlamydomonas; at C is a single Colpodella, without the nucleus, and much swollen anteriorly. Finally the Chlamydomonas is, as it were, eviscerated, nothing but the body walls being left. After this wholesale plundering of the contents of the Chlamydomonas, it then passes into a "cell" or encysted state, as at D (*a*, the mass of food, colored red). The contents of the cell then break up into a number of masses, as at E, which finally, as at F (the masses destined to change into zoospores), issue from the cyst in a mass surrounded by a thin membrane, which gradually disappears, when the free zoospores make off in every direction. G represents the encysted body of the monad, without the ball of food. He also shows that another unknown monad, a species of Bodo, and three species of Pseudospora also develop by becoming encysted.

Messrs. Dallinger and Drysdale describe in two unknown monads the process of encysting and the development of zoospores, the sarcode mass passing through a process resembling the segmentation of the egg into four, eight and many spheres, each sphere ultimately becoming a monad. The changes were noticed with greater fulness of detail in another unknown monad, Fig. 21, A. When about to pass into the encysted stage it became amœboid in its form, but still very active; at the stage B, however, it became spherical and quiet, and finally lost the flagellum,

Fig. 21.



Development of a Monad.

and the contents suddenly divided into four portions, separated by a white cruciform mark or furrow. Then an intense activity pervaded the sarcode mass, "a sort of interior whirling motion" like the rushing of water "round the interior of a hollow glass sphere on its way to the jet of a fountain," as indicated at C. This action lasted from ten to seventy minutes, when it stopped and the mass broke up into small embryonic zoospores, as at D, which began a "quick writhing motion upon each other, like a knot of eels." After remaining in this state from seven to thirty minutes, they separated and swam away. Thus far they had

passed through the ordinary mode of formation of young monads, but the authors noticed among the swarm of monads some much larger, and differing from the others in being very granular towards the flagellate end. These fastened themselves upon one of the smaller common forms, Fig. 21, E, and finally absorbed it, a process certainly analogous to, if not identical with, conjugation. It then assumed a resting condition, as at F. The sphere then opened slowly and a glairy looking fluid poured out. On careful examination of this fluid, with powers of 2500 to 5000 diameters, seven hours after emission tiny dots, semitransparent and yellowish, appeared as at G. In an hour and ten minutes the dots appeared as at H; after two hours more as at I. The sharp-pointed bodies at I became rounder, and from the pointed end a flagellum developed as at J, when they were ninety minutes older than at I. At this time "motion first showed itself; this, however, was not the motion usual to the monad, but a motion of horizontal vibration from *a* through *b* and *c*, to *d*, and then back again." It then swam away, became plump as in K and then was followed into the stages from A to E, the last figure (L) representing the complete monad, thus passing through two cycles of existence.

Three modes of development in the Flagellata seem therefore established, as follows:—

1. Simple fission.
2. The production of monads by encysting.
3. The production of monads by encysting and conjugation, with a resting stage and the production of excessively minute zoospores which grow, finally becoming normal monads.

It will be seen that these methods of increase are paralleled by those observed in the Monera, the Gregarinida and the Rhizopoda. It appears that there is here nothing like a sexual development, unless we have something analogous to it in the conjugation (?) of the monads described by Dallinger and Drysdale, but which they themselves do not call conjugation, merely confining themselves to a statement of the facts observed by them.

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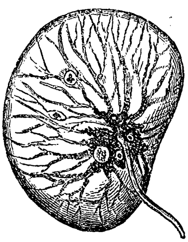
VI. THE NOCTILUCÆ.

Tossed from one place to another among the Protozoa, we have now, thanks to the researches of Cienkowski, certain grounds for placing the Noctilucæ near, if not among the Flagellata, from the resemblance of the zoospores to the monads; while they seem to form a more highly developed type. It thus appears that by a study of the mode of growth of the Protozoa, as in the rest of the animal world, we can alone obtain correct ideas as to the affinities of the respective groups.

The Noctiluca (Fig. 22) is a highly phosphorescent organism, so small as scarcely to be seen with the naked eye, being from ·01 to ·04 inch in diameter. It occurs in great numbers on the surface of the sea. It has a nearly spherical jelly-like body, with a groove on one side from which issues a curved filament, used in locomotion. Near the base of this filament is the mouth, having on one side a tooth-like projection. Connecting with the mouth is an œsophagus which passes into the digestive cavity, in front of which lies an oval nucleus. Beneath the outer skin or firm membrane surrounding the body is a gelatinous layer, containing numerous granules. A network of granular fibres arises from the granular layer; these fibres pass into the middle of the body to the nucleus and digestive cavity.

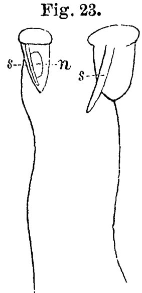
Fig. 22.



Noctiluca miliaris.

Development. Baddely had noticed a multiplication by division and reproduction by internal buds, and Busch had observed round, transparent disks, of the same size, consistence and optical properties as the Noctilucæ occurring among them, but could not determine what relations they bore to the former. It was, however, reserved for Cienkowski to trace the development of monad-like zoospores in these reproductive bodies. Fig. 23 represents these zoospores. They move about by a long flagellum. The tooth-like process (*s*) is thought by Cienkowski to be a rudimentary condition of the "whip" near the mouth of the adult Noctiluca. By keeping specimens in a drop of water on a thin glass which was placed over a moist chamber so as to ex-

Fig. 23.



Zoospores of Noctiluca.

clude all access of dry air to the water in which the animals were living, he was enabled to observe them for twelve hours. The stages he observed were—

"1st. Noctiluca-like bodies, but without mouth or lash, and having a doubly spherical or so-called biscuit form, each partial sphere having a granular protoplasmic mass with fine branching rays, the two masses being connected more or less. 2d. The protoplasm connects so as to form a disk on one pole of the irregular double spheroid, which gradually becomes spherical, exhibiting three or four depressions at one pole. 3d. The formation of the disk is preceded by a segmentation of the entire mass of the protoplasm of the Noctiluca into two, four, eight, sixteen, etc. parts, after which the disk begins to grow up on the surface of the Noctiluca. 4th. The protoplasmic disk sends out stumpy processes which project from the surface of the spheroid and exhibit peculiar wriggling movements. 5th. The mass commences to divide into smaller pieces, the vesicle being now quite spherical. The commencement of this division was not directly observed, but later stages, in which clumps of protoplasmic matter were seen arranged at first in groups of eight; these, then, were followed carefully through their division into groups of sixteen irregular, oblong particles. These products of division appear like denser, sharply-defined masses or nuclei, lying in a less dense surrounding granular plasma. 6th. The next stage was one of the first and most commonly observed, in which the protoplasmic disk, formed as above described, has become entirely split up into small oval bodies, each ·016 millimetre long. The aggregated mass of these oval spores sometimes appears as a disk at one pole of a Noctiluca-like vesicle, or as a girdle passing round it. 7th. By high powers each oval particle is seen to have a terminal cilium, and whilst under observation many were seen to separate from the disk and swim about as free swarm-spores" (Fig. 23).

Cienkowski also observed the fusion of two Noctilucæ. "The two animals place themselves with the two so-called 'oral apertures' close to one another, and through these a protoplasmic bridge is formed, which unites the nuclei of the two individuals. Later, at the points of contact, the outlines of the two Noctiluca-vesicles fuse, and thus the double-spheroid or biscuit-shaped bladders are formed. By further fusion the pinching in of the vesicle disappears from one side, so that the vesicle becomes more nearly

spherical. Meanwhile the two nuclei become completely fused into one, retaining, however, their radiating threads and network, as in normal individuals. The cross-striped 'lashes' and the 'teeth' of the two fused Noctilucæ also disappear. All trace of the double origin of these 'copulated Noctilucæ' may pass away by the disappearance of the fold on the surface, near to which the nucleus lies, and thus a Noctiluca vesicle is formed, which is always larger than the normal Noctiluca, and seems identical with the bodies noticed by Busch, and also very probably identical with the biscuit-shaped and spherical Noctiluca vesicles in which Cienkowski has traced the formation of the swarm-spores. A direct observation of the formation of swarm-spores in the copulated forms Cienkowski was not able to obtain."

This fusion of two Noctilucæ is not, however, essential for the production of zoospores, as they appear whether conjugation has occurred or not. When it does occur, however, it seems to be of a sexual nature. Conjugation, though by no means necessary, does frequently take place, and "as in the fusion of the zoospores of Myxomycetæ, and the copulation of Actinophrys, and others, leads to an augmentation of the mass of the protoplasm." "Zoospores," he adds, "occur in quite small Noctilucæ, which certainly could not be the product of the fusion of two individuals. Sometimes the zoospores develop very rapidly whilst still in the disk, and their protoplasm becomes differentiated into a nucleus and radiating threads." Cienkowski considers that the zoospores of Noctiluca decide the systematic position which must be assigned to this organism. It seems to him that they are animals of large dimensions belonging to the division of the Flagellata.

A single mode of growth, therefore, occurs in Noctiluca, *i.e.* development from zoospores.

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